Anatomy of a group model-building intervention: building dynamic theory from case study research[1]

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Abstract

The system dynamics group at the Rockefeller College of the University at Albany has been developing techniques to create system dynamic models with groups of managers during the last 25 years. Building upon their tradition in decision conferencing, the group has developed a particular style that involves a facilitation team in which people play different roles. Throughout these years of experience, the group has also developed several "scripts" to elicit knowledge from experts based on small-groups research, and well-established practices in the development of system dynamics models. This paper constitutes a detailed documentation of a relatively small-scale modeling effort that took place in early 2001, offering a "soup to nuts" description of group model building at Albany. The paper describes in detail nine of the scripts that the group has developed, offering some reflections about their advantages and limitations. Copyright © 2006 John Wiley & Sons, Ltd.

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Introduction

Involving client groups in system dynamics model building, particularly in matters of strategy and policy, presents a number of method issues (Vennix *et al.*, 1994; Vennix, 1999; Rouwette *et al.*, 2002). Examination of these issues has increased since the first documented experiments in the late 1960s and have spanned a wide variety of group modeling techniques and conceptualizations of the group model-building (GMB) process (Rouwette *et al.*, 2002; Zagonel, 2002; Otto and Struben, 2004). The issues examined include how to deal with individual and group constraints on information-processing capability, problems of knowledge elicitation, dealing with multiple perceptions and constructions of reality, the impacts of the selected modeling tools, and the impacts of the facilitation process (Vennix *et al.*, 1994; Vennix, 1999).

This paper contributes to that body of work by presenting an in-depth examination of how these issues were treated in a group modeling process combining system dynamics modeling and related group decision-making

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methods. This particular GMB effort was completed over a 4-month period in 2001, and it was designed following the procedures and methods developed at the University at Albany. In addition to presenting a detailed description of the process, and the products associated with the project, the paper also documents the effort needed to accomplish the objectives by both modeling and client teams. The paper extends the discussion about the use of scripts to develop system dynamic models with groups, as initiated by Andersen and Richardson (1997), presenting two new scripts and detailed descriptions and process products of seven scripts more.

The case presentation constitutes a "soup to nuts" description of the Albany GMB approach. The description also includes some process-related products published for the first time.[2] These products illustrate the results obtained in the case and assist other system dynamics practitioners to replicate the experience. The perceived success of the experience reported in this paper encouraged continued effort in model building that has extended into 2005, including GMB to examine the dynamics of information integration in intergovernmental projects.

Following this brief introduction, the paper is organized into four sections. The first of them consists of a review of previous research in GMB. The next section includes a description of the specific GMB effort documented in this paper. The following section contains a description of the eight scripts used in the GMB, and the final section includes a series of concluding remarks.

Previous research

During the last 25 years, researchers at the University at Albany have developed approaches to decision conferencing[3] using a combination of group facilitation techniques linked to a variety of computer models developed with the group in a meeting setting (Rohrbaugh, 1992). The approach has been used successfully to understand and tackle problems in areas as diverse as expert estimation and forecasting (Mumpower and Stewart, 1996), bargaining and negotiation (Mumpower *et al.*, 1988), resource allocation (Milter and Rohrbaugh, 1985), investment decisions in information systems (Schuman and Rohrbaugh, 1991; Larsen and Bloniarz, 2000), and policy analysis using system dynamics (Reagan-Cirincione *et al.*, 1991; Richardson *et al.*, 1992; Richardson and Andersen, 1995; Andersen and Richardson, 1997; Kelly 1998; Rohrbaugh, 2000). The group has also developed an approach to evaluate group processes (Quinn and Rohrbaugh, 1983; McCartt and Rohrbaugh, 1989, 1995). Decision conferences, including system dynamics group model building, fit within a larger body of work in group decision support grouped under the umbrella of the term Group Decision Support Systems (GDSS).[4] In this way, GMB builds upon the knowledge of two main threads of knowledge: decision conferencing and system dynamics practice (Zagonel, 2002).

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Table 1. Fit profiles of task type and support technology needs

Task type	Communication support	Process structuring	Information processing
Simple	High	Low	Low
Problem	Low	Low	High
Decision	Low	High	High
Judgement	High	Low	High
Fuzzy	High	Medium	High

Adapted from Zigurs and Buckland (1998, p. 326).

GMB presents participants with considerable challenges and task complexity, more so than in some other group decision processes. The way the methods in the case presented here deal with these challenges can be described in terms of the framework developed by Zigurs and Buckland (1998). Based on an extensive review of the decision support research, they relate the type of tasks faced in a group decision situation to the communication support, process structuring, and information-processing demands according to the scheme shown in Table 1. The table identifies the support and facilitation technology needs in relation to five task types. The types are distinguished by outcome multiplicity, solution scheme multiplicity, conflicting interdependence, and solution scheme/outcome uncertainty. Using these criteria, the tasks presented to the participants in group system dynamics modeling are a mix of simple, problem, decision, judgement, and fuzzy tasks. This suggests that the support technology should be high functioning on all three dimensions: communication support, process structuring and information processing. These communication and process technology requirements are reflected in the GMB approach presented here.

Process-structuring requirements are addressed in this approach to GMB in part through defining roles for the facilitating team: facilitator, modeler/reflector, process coach, reflector, recorder and gatekeeper (Richardson and Andersen, 1995). The roles are clustered in two groups to take responsibility for two specialized tasks: facilitation and analysis, the two pillars of decision conferencing (Rohrbaugh, 1992; Vennix *et al.*, 1994; Richardson and Andersen, 1995; Zagonel, 2002). In a recent work, Zagonel (2004) identified a tension between these two groups of specialized tasks. While the facilitation tasks are oriented to help group members to negotiate differences in their views about a problem (the model as a "boundary object"), the analysis tasks are more concerned for building a model representation that helps team members to understand the consequences of their decisions (the model as a "micro-world"). Communication support requirements are addressed by room configuration and by continuous feedback from the GMB team. Finally, information processing is supported by the use of system dynamics tools such as reference modes, causal diagrams and simulation models.

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The role definitions and behavior expectations are expressed in a series of "fairly sophisticated pieces of small group processes" called scripts (Andersen and Richardson, 1997, p. 107). Scripts are conceptualized as a series of divergent or convergent activities to facilitate the cognitive processes of eliciting information, exploring courses of action, and evaluating situations (Vennix *et al.*, 1994; Andersen and Richardson, 1997). Scripts serve as both process-structuring and communication support devices and provide for division of labor with respect to some information-processing needs according to the complexity of each task type. The scripts, facilitation methods, and specific modeling methods are organized through a collaborative planning process that engages the modelers and client teams.

Project description

Objectives

The GMB effort described in this paper was initiated as a theory-building effort in the course of a longitudinal research project on government Information Technology (IT) innovation conducted by the Center for Technology in Government (CTG).[5] The main purpose of the effort was to explore the feasibility of applying system dynamics modeling to a complex interorganizational process. The process to be modeled was the subject of field research focused on knowledge and information sharing in interorganizational networks (KDI project).[6] This project had produced a large volume of observational and interview data and preliminary analyses about seven technology-related projects in government agencies.

In the course of collecting and analyzing data from this project, CTG researchers noted evidence suggesting important feedback effects influencing the collaboration and knowledge sharing that are critical to interorganizational information system conceptualization, design, and deployment. From initial conversations between CTG staff and the system dynamics group at Albany, it seemed that applying system dynamics methods to this process had potential to yield valuable insights into collaboration research and practice. As a novel application of the methods it had potential to yield new modeling insights as well.

Project time-line

The GMB activities took place from January to May 2001 (see Table 2). During the first meeting, the modeling team contacted the director of research at CTG to explore the idea of using system dynamics methods to analyze case data generated at the center. In this way the research director started playing the gatekeeper role, as described by Richardson and Andersen (1995). During these initial conversations, the modeling group learned about the KDI project,

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Table 2. Project time-line

Date	Activity	Participants
January 2001	Modeling group starts conversations with CTG's gatekeeper and potential participants	3 modelers 1 gatekeeper
13 March 2001	First project scoping meeting	3 modelers 1 gatekeeper
20 March 2001	Second project scoping meeting	3 modelers 1 gatekeeper 7 members of client team
29 March 2001	Third project scoping meeting	3 modelers 1 gatekeeper 4 members of client team
13 April 2001	First modeling session	4 modelers 1 gatekeeper 4 members of client team
8 May 2001	Second modeling session	4 modelers 1 gatekeeper 4 members of client team

and about theoretical conversations related to trust and collaboration within the CTG team.

In three project-scoping meetings, the modeling team and center staff worked through assessing the suitability of system dynamics to aid theory development conversations at the center, setting the main objectives and expected products of the GMB sessions. The group also decided to focus the modeling effort on one of the seven cases from the KDI project: the development of the Homeless Information Management System (HIMS).[7]

The GMB sessions took place in two 4-hour meetings (April 13 and May 8). The first meeting focused on the elicitation of the dynamic characterization (reference modes and a dynamic hypothesis) of the collaboration mechanisms present in the HIMS case. The second modeling session focused on the presentation and exploration of a simulation model of the case.

Effort on project

The current section includes a description of the amount and distribution of effort required to accomplish the project objectives, and provides a reference "picture" of the effort needed for similar initiatives using this GMB approach. The amount of effort documented includes the activities of both the facilitation and the client groups.

FACILITATION TEAM ACTIVITIES AND EFFORT The GMB project required a total of 155 person-hours from the facilitation team (see Table 3). The facilitation team

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Table 3. Facilitation team effort

Activity	Participants	Person-hours	Percentage
Coordinating effort	2	15	9.7%
Concept model	2	20	12.9%
Planning meetings	3	15	9.7%
Facilitation	4	32	20.6%
Model formulation	2	45	29.0%
Writing reports	2	20	12.9%
Gatekeeping	1	8	5.2%
Total		155	100.0%

consisted of five members: two senior modelers, two junior modelers, and a gatekeeper. To calculate the total effort (person-hours) we multiplied the number of persons engaged in the activity by the duration of each activity in hours.

Activities in Table 3 can be grouped into four main groups: model formulation, facilitation, managing collaboration and planning. Managing collaboration included coordinating the effort, writing reports, and gatekeeping. Planning activities included developing a concept model and planning the scripts to be used during the sessions. In summary, modeling and facilitation activities represented about half of the total effort on the project (about 30% and 20%, respectively). Planning activities and managing collaboration activities accounted for the other half of the effort (about 25% each).

CLIENT GROUP ACTIVITIES AND EFFORT The client group effort was 68 person-hours (Table 4). The five activities listed in Table 4 could be grouped into two categories: scoping and GMB sessions. The participation of the client group in defining the scope of the project represented about 40% of the total effort, and the actual participation in the GMB meetings represented 60% of the total effort.

Gatekeeping is often a key role in decisions about the involvement of other members of the client organization in scoping activities. In some GMB projects, the gatekeeper is the only client involved in these planning activities. Given

Table 4. CTG's client group effort

Activity	Participants	Person-hours	Percentage
First project scoping meeting	1	2	3%
Second project scoping meeting	8	16	24%
Third project scoping meeting	5	10	15%
First modeling session	5	20	29%
Second modeling session	5	20	29%
Total		68	100%

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the nature of the project and CTG's organizational culture, however, the team decided to engage the KDI team in the scoping process.

Project products and data

The results of GMB-related activities include process-related products and reports, and a series of conference presentations reporting on the project results. The process-related products include personal notes, scripts, agenda, artifacts, and reports from the GMB sessions. These process-related products constitute the data on which this paper is grounded. The simulation model constitutes the main artifact of this initial exploration with the CTG team. However, the exploration also demonstrated that system dynamics can be an effective tool for building theories about collaboration, trust development, and knowledge sharing in information technology projects in interorganizational contexts.

Scripts for group model building

The scripts used in this case followed the general framework developed in several other interventions facilitated by the modeling group at Albany (Andersen and Richardson, 1997). Each script is organized into three subsections. The first describes the script's objective, the second subsection describes how the script is to be used, and the last subsection includes a brief assessment of the application of the script. The series of scripts presented in this section and the previous project description constitute a comprehensive description of this GMB approach.

Script 1: scheduling the day

Objective Planning each GMB intervention requires selecting the scripts to be used during the modeling session. As described in previous work (Andersen and Richardson, 1997), the appropriate metaphor for this planning stage is preparing for a theatrical performance. This includes creating a detailed plan of divergent and convergent tasks to elicit variables and model structure combined with continuous reflections about the process, facilitated by presentations from the modeler/reflector. The central focus of attention for this session is creating a communication artifact, the final schedule for the modeling process. This artifact is used by the facilitation team to coordinate the performance. Typically the format of the final schedule is a planning sheet that includes three to four columns. The first column shows the scheduled times for the activities; the second column includes the public agenda to be shared with the group; the third column includes a detailed agenda to be used by the team; and the last column includes notes about the preparation and materials needed for each part of the meeting (see Table 5).

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Table 5. Skeleton of a meeting agenda

Time	Public agenda	Team agenda	Preparation and materials
Pre-meeting			
8:30			
8:45			
. . .			
10:20	Break		
10:30			
10:45			
. . .			
12:30	Lunch		
Post-meeting			

PROCESS In this particular project, the planning script incorporated a series of pre-meeting and post-meeting activities. The pre- and post-meeting activities involved engaging the gatekeeper in the planning process to get feedback about the appropriateness of the initial plan, as well as the preparation of materials and reports to the client group.

This planning technique provides for structuring the process at a fairly detailed level, using time blocks of 15–20 minutes, although some tasks can take more than one block. The decision making for creation of the planning table was iterative. That is to say, the group started by scheduling the specific tasks for the meeting, coming back to the pre- and post-meeting activities at the end of the planning session. Ideas about the preparation and materials needed were added during the initial scheduling, but new ideas were incorporated in a final review of the schedule. The initial plan for GMB sessions was developed in a 2-hour meeting for each session.

ASSESSMENT The planning stage was previously compared to preparation for a theatrical performance. However, the execution phase is much more improvisational, and is better compared to a "chess player, a jazz musician in concert, or a football coach executing a game plan. All three of these examples have in common the notion of flexible improvisation after compulsively detailed advance planning" (Andersen and Richardson, 1997, p. 113). This aspect of the modeling process resembles the fuzzy task type described above.

The group has developed some strategies to make changes to the session plan during the execution. It is common to have a brief meeting just before the GMB session, and several conversations during the break to adjust or redirect the course of the meeting. In fact, the modeler/reflector sends signals to the facilitator as in a baseball game, asking for permission to redirect or focus a conversation or to force a break to discuss alternatives to the facilitation process. Based on the flow of the group process, the facilitator can respond to, ignore, or delay attending to the modeler/reflector's signals.

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Script 2: logistics and room arrangements

OBJECTIVE The commitment and attention of the group to the model-building tasks, particularly over an extended period of time, is critical to success. This commitment depends in part on the qualities and comfort of the physical facilities and the smooth handling of logistics for the sessions. This should include removing the participants from their phones and work site and providing a relaxing change from routine work. Multi-day sessions should be located and planned to provide high-quality lodging, meals, and opportunities for social interaction. As one senior facilitator once told us, "Get any team away from their phones, feed them well, and take care of their needs and they will do brilliant work." Physical facilities are related to the communication support described above.

High-quality physical facilities include large whiteboards, smooth blank walls to post pieces of paper with ideas from the group, movable tables and chairs allowing flexible seating, overhead projector for showing hand-drawn acetate slides, digital projector connected to a laptop for software-based models, and 8-hour chairs (a term of art used by most off-site logistic managers to refer to seating for a full day's work).[8]

PROCESS For this case very little attention to these space requirements was necessary. CTG routinely uses group facilitation processes in its work and adheres to the same meeting requirements and rules as those for group modeling. CTG spaces met or exceeded all the meeting room requirements described above.

Figure 1 is a photograph of a CTG meeting space, showing the facilitator in front of the group and two tables with a computer and projection equipment. The U-shaped seating configuration allows all participants to see each other when they speak. Three of the room's walls are predominately whiteboard space. The photograph was taken from the seating position of the recorder and the modeler/reflector.

ASSESSMENT For this case there was little effort or complexity involved in room set-up and logistics, in getting all the physical aspects of a meeting in excellent condition. This is not typically the case.[9] However, in this example, there was ready access to specially designed space at CTG's home office.

Script 3: hopes and fears

OBJECTIVES The "hopes and fears" exercise is often used as an opening activity for a group modeling session. As used in this case it structures the process and supports both focused communication and information processing. There are several possible objectives depending on the type of group that is doing the work. First, if the group has not worked together in the past, this can be a

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Fig. 1. Room configuration during a modeling conference

group-forming exercise. Participants can introduce themselves as they state their "hopes" and their "fears" for the project. Second, in stating their hope or fear many members make a small speech to the group. If left untold at the beginning, these small speeches often emerge at more disruptive times during the group process. Third, this exercise can help the group identify and share its own goals for the modeling project. The facilitator can often return to this list at the end of the day as a way to measure progress of the project against original intentions. Finally, this exercise often surfaces an interesting list of goals, barriers and key values to success for the problem under study. These statements differ from goals for the GMB in that they often reflect interests of stakeholders not present or are goals for the system under study, rather than for the group modeling process itself.

PROCESS The process elicits and clusters statements of hopes and fears from the group members in a structured process founded on the Nominal Group Technique (Delbecq and VandeVen, 1971). Members of the group are given pieces of colored paper—one color for statements of hopes and the other for fears. The participants are instructed to write simple phrases identifying one hope or one fear on each colored sheet. Usually, the facilitator writes a task-focusing question on a flipchart such as "What are your hopes and fears for this project that we are working on for the next several days?" Initially participants

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write these phrases working alone to assure maximum diversity of ideas and to avoid anchoring. Then, in a round-robin fashion, each individual is asked to read one hope and one fear sheet to the group. If the group is just forming, individuals are asked to introduce themselves before reading their hopes and fears.

As each sheet is read the facilitator collects it from the participant and posts it on a wall, clustering the hopes and fears into similar groups interacting with the participants. The facilitator leads the group in discussing the placement of sheets and the meaning ascribed to the clusters. The round robin collection of ideas continues until all members of the group have had a chance to get all of their ideas out. A member of the modeling team usually steps back and gives an interpretative reading of the finished and clustered wall, trying to give a single voice to this first group exercise, and creating a shared understanding of the group's goals and concerns. If the group is very large and time is short, we sometimes ask the group to break into pairs or small groups of three or four for the final posting of the pieces of paper on the wall. The recorder captures the list in some format that preserves the clusters (using a camera or a word processor). The process took about 30 minutes in this particular case.

Assessment Our group produced a simple unclustered listing of hopes and fears. Since the group had been working together for some time, this exercise did not serve any significant group building function. However, almost all of the hopes and fears pertained to the group process itself. This group was most concerned about the value of system dynamics modeling per se, and its value as a theory-generating exercise for them. Their comments were quite frank (e.g., "This is a waste of time" as a fear) and the group valued humor ("There is humor in today" was a hope of one participant). The facilitator returned to this list of hopes and fears at the end of the first day and near the beginning of the second as a bench-marking exercise for the group's perceived progress.

Script 4: concept model

Objectives From the hopes and fears exercise, the conference moves to the presentation of a concept model, i.e., a small model with three to four stocks and two or three feedback loops. The content of the model is always closely related to content of the problem at hand (see Richardson, 2006, for several examples of concept models and a detailed discussion about how to use them and potential problems with the approach).

The concept model script is designed to accomplish several objectives. The first of them is to clarify expectations about the final products of the GMB exercise. In many cases, the client group has no experience with simulation models of any nature, and having an early example helps them visualize the main target of the activity. Second, the concept model is used to introduce the

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grammars and the basic principles of system dynamics. The concepts of stocks and flows are introduced by the use of a simple structure that uses variables familiar to the client group. The iterative nature of the method is exemplified by presenting the model in two or three stages, showing behaviors associated with partial simulations of the concept model. Through the incremental addition of structure and the partial simulations, the client group also learns about the relationship between model structure and model behavior, and that the model is transformable. Finally, the model is used to start the conversation about the problem in dynamic terms.

PROCESS The presentation of the concept model starts with a brief introduction to stocks and flows as ways of representing a process. The modeler/reflector usually starts by drawing in a corner of the board or in a flipchart the image of a bathtub with a faucet and a drain. Using the image of the tub, the modeler explains that stocks are analogous to the bathtub; and flows, to the faucet and the drain.

The modeler then introduces the images used in a stock-and-flow diagram using the first iteration of the concept model, presenting it as a story accompanied by a hand drawing in the board (see Figure 2a). The modeler/reflector then comments that it is possible to formulate some algebra associated with the picture on the board, and that it is possible to use a computer program to create this mathematical model, projecting an image of the drawing in a system dynamics software application, usually showing at the same time the hand-drawn picture and the computer-generated picture (Figure 2b). The modeler usually shows some of the equations in the model describing basic assumptions of it.

The modeler explains that once some algebra is built into the drawing the computer can calculate the way in which the variables in the diagram behave over time, then runs the model. The results of the run show how the dynamic behavior of a system can be expressed in terms of graphs over time (Figure 2c). The results are discussed in such a way as to clearly communicate that system structure is tightly connected to system behavior. Thus, the structure shown in Figure 2(b) produces the behavior shown in Figure 2(c).

The modeler proceeds to identify many ways in which the model is wrong, and how it can be modified to make a richer, more appropriate picture of the problem. The modeler then adds some additional structure to the whiteboard image, telling a story of a new assumption represented in the model. It is common to choose changes that "close loops", so the changes help to introduce the nature and differences between reinforcing and counterbalancing processes. Then, using the projection of the computer-based model, the modeler shows the new image, runs the model, and shows the new behavior. The model's behavior with the new piece of structure further demonstrates how variations in structure affect how the model behaves over time. In this particular case, the presentation consisted of three iterations in which structure was

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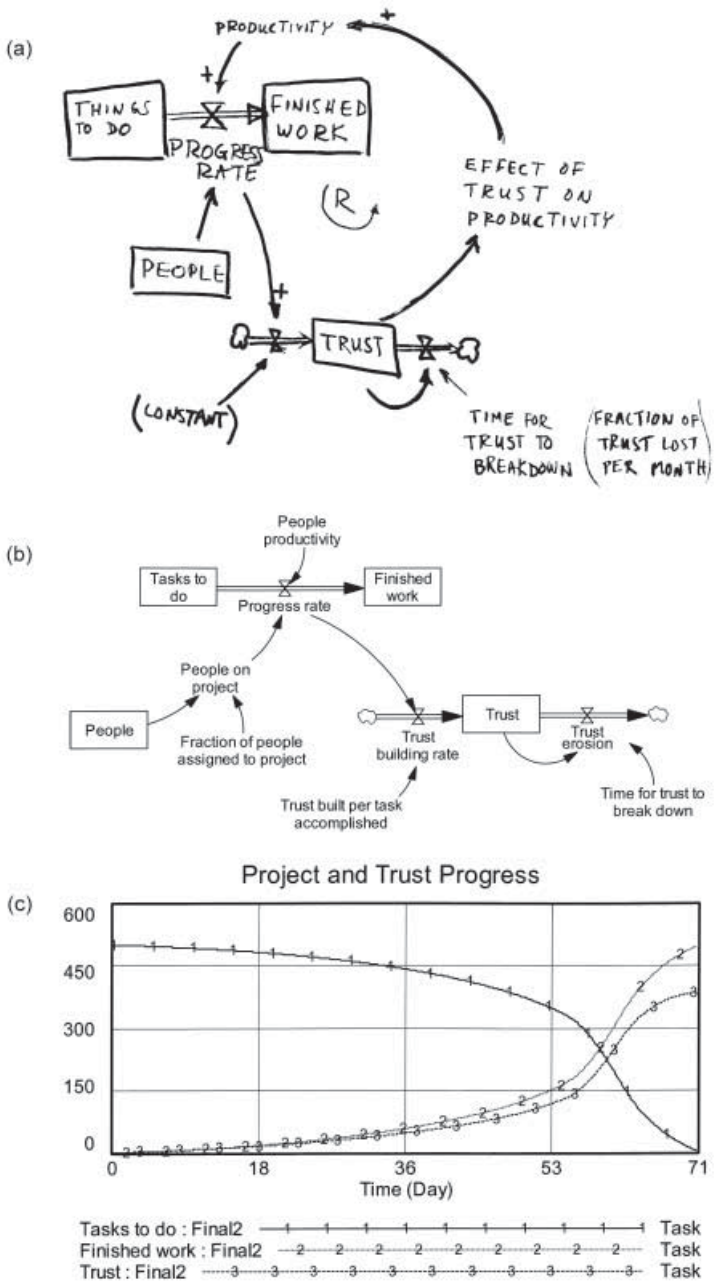

Fig. 2. Concept model sequence of structures and behavior (images captured from the board and Vensim)

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added, and new behaviors were discussed by the group (Figure 3). The whole exercise took about 20 minutes.

ASSESSMENT Given the pedagogical and practical purpose of the script, we have found that concept models are tricky to build. From the group experience, these are some principles or heuristics to guide the formulation and presentation of concept models:

- Use a simple image such as the bathtub to explain the concepts of stock and flows.
- Present only three to four stocks in the first iteration of the model.
- Use algebra that will be easy to understand by the client group, even if that implies the use of weak formulations.
- Use a clearly unrealistic model, so the group can develop it.
- Name variables in a conceptual rather than a mathematical way (i.e., avoid names that include words such as "ratio").
- The structure added in each iteration should make dramatic differences in model behavior.
- Show the most striking or realistic behavior in the last iteration.
- Use two or three versions (iterations) of the concept model.

A concept model has to lead to participants' objections about the theory represented by it, so they engage in a conversation to fix it, creating a more adequate theory of the problem. A problematic concept model would be one that is accepted by the group, limiting further explorations of the problem. In this way, the model has to be technically correct, but "agonizingly inadequate" (Richardson and Andersen 1995, p. 114).

Script 5: variable elicitation

OBJECTIVES Variable elicitation is a script used to start the group conversation about developing a consensus-based model of the problem, and a conversation about the problem boundaries. The objective is to identify as many problem-related variables as possible, prioritizing them and making an effort to identify key stocks to be used in the modeling. The key variables elicited in this process are usually the main input to other activities during the session.

PROCESS Variable elicitation is similar to the process described in the hopes and fears script above. The script initiates with a divergent exercise usually done individually. Participants are given sheets of paper and asked to write as many problem-related variables as they can. The facilitator writes a task-focusing question on the whiteboard or flipchart, such as, "What are the key variables affecting the process and outcomes of the HIMS project?" The facilitator gives people a few minutes to work individually on their lists. Once they

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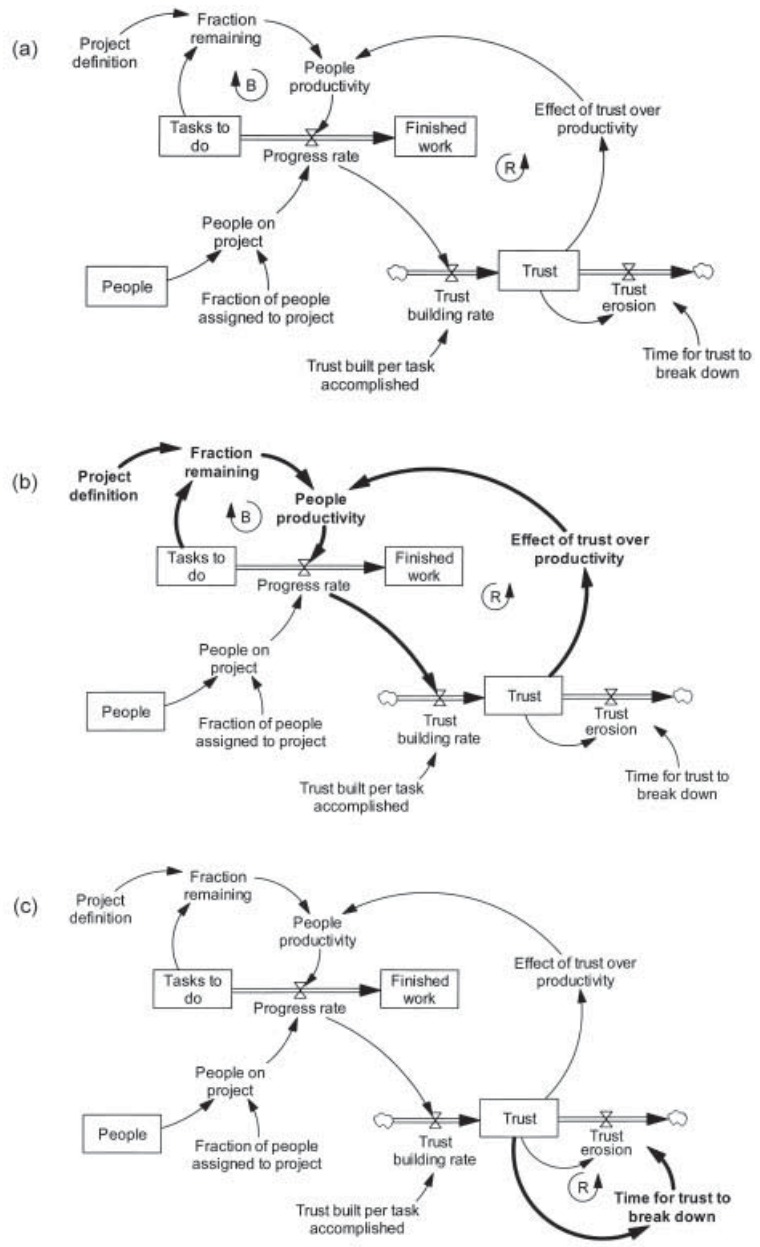

Fig. 3. Concept model sequence of added structure (images captured from Vensim)

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have finished the individual exercise, the facilitator uses the same process used in the hopes and fears script to put all individual variables on the board. When a variable name is open to several interpretations, the facilitator asks for a brief description or definition of the variable, including the units in which the variable can be measured. The facilitator writes the variable name on the board, including any additional information in parenthesis.

The second phase of the script is a convergent activity in which simple voting mechanisms are used to prioritize the variables. Usually, individuals can vote for as many variables as they want. The number of votes for each variable is also written down on the board. A member of the facilitation team makes a summary of the variables on the board, while the recorder captures the products of the process either photographically or in a word processor. The complete script took from 15 to 20 minutes: 5 minutes for the individual work and the rest for sharing and clarifying variables.

ASSESSMENT System dynamics practitioners and researchers have developed several guidelines to name variables (see, for example, Chapter 2 of Richardson and Pugh, 1981). The facilitator uses these guidelines to assess whether a variable elicited from the group is open to several interpretations. Participants in a GMB session do not follow these guidelines when naming variables at first, but usually know how they are measured because they manipulate these values on a day-to-day basis. In this way, asking for units is a helpful way to clarify the meaning and to choose a proper name for each variable. Moreover, it prepares the participants to think in these terms when drawing reference modes.

Although the script is only the very initial part of the knowledge elicitation, it is important to start working towards the identification of key stocks and rates to be used in the elicitation of the problem structure. Usually, the facilitator suggests to the group which variables can be considered stocks as they are mentioned. If the group agrees, he can add the words "level of" to these variables as he writes them on the board. This effort is important for the structure elicitation phase as practiced by the group, which usually focuses on stocks judged as important by the group.

Script 6: reference modes elicitation

OBJECTIVES Once a series of variables has been elicited and prioritized, the next script typically involves the elicitation of reference modes associated with those variables. In some cases a series of reference modes can be prepared in advance with the help of the project gatekeeper. However, the group frequently engages in defining reference modes when the problem lacks a precise dynamic definition. The objective of this script is twofold. First, the task is designed to elicit as many dynamic behaviors and stories about those behaviors as possible. Second, the script provides for continued probing of system boundaries,

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purpose, audience, and policy levers of the problem. These are key inputs to problem definition and the creation of initial vignettes of a dynamic hypothesis.

PROCESS Reference mode elicitation is mainly a divergent task. It starts with participants working alone, in pairs, or in triples to draw graphs representing behaviors over time of individual variables deemed important. Usually, the facilitator writes a task-guiding description on the board. The description asks the group to use a separate sheet for each variable, with the horizontal axis for time, marking the initial and final dates of the behavior sketched. They then draw a line showing changes in the chosen variable over that time frame, and annotate the graph with any important event that helps to explain changes in the behavior of that variable. The facilitation team usually spends time walking around the room, attending to questions and helping them in their thinking process.

Once the pairs or triples have finished their work, they start sharing each reference mode accompanied by a "story" that explains the behavior in the graph. The facilitation team probes frequently to clarify time boundaries, important events, processes, and actors involved in the problem at hand. In order to assure that all individuals share their thoughts, each presents one reference mode at a time, proceeding to each member of the group in several iterations. The modeler/reflector frequently asks permission to participate proposing images that clarify the conversation or redirects the conversation about continuous, dynamic processes. The complete activity usually takes about 45–60 minutes: 15 to the individual work, and the rest sharing behaviors and stories.

ASSESSMENT Probing, and reflecting back to the group in ways that help the process of boundary clarification, are important elements in effectively defining the problem and eliciting its dynamic behaviors. The guided process helps the group to create consensus about main processes, actors, and time boundaries for the problem. In this particular GMB intervention, the conversation led the group to agree upon four main stages in the HIMS project: developing a business case, developing a prototype, looking for funding for the project, and implementation. They also agreed that the modeling effort's main focus was on the prototype development phase because the most interesting dynamics occurred during that phase.

Script 7: structure elicitation

OBJECTIVES The next task during the conference consists of eliciting from the group a causal structure that explains the system stories and behaviors discussed in the previous activities. The purpose of the activity is to capture the key endogenous mechanisms that have the potential to explain the observed behaviors or dynamic hypotheses.

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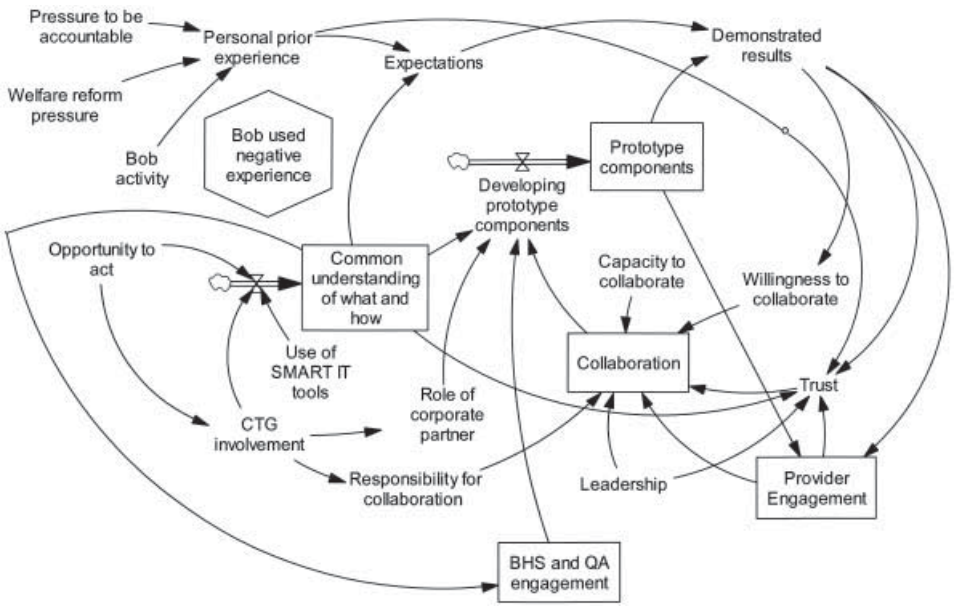

Fig. 4. Structure elicited from the group (captured from the board in Vensim)

PROCESS The group has followed several variations of a script to elicit model structure. For this specific case we used a straightforward direct elicitation of structure. During the scheduled break after the reference mode elicitation script, the facilitation team selected a couple of key processes from the morning conversations: building the prototype and the development of understanding the benefits of HIMS. In this way, the facilitator started the eliciting process by suggesting that CTG's involvement in the HIMS project consisted of building two stocks: prototype components, and common understanding of the shared information system (stocks at the center of Figure 4). The facilitator explained that these stocks were initial simplifications of the system. For example, the stock of "prototype components" aggregated all project products identified earlier.

The facilitator then asked the group to identify the variables that help to open or close the faucet of these two stocks. The client group started to suggest causal relations linked to these two initial stocks and their corresponding rates. The facilitator continually probed the group about the nature of the causal relationships while drawing them on the board. After adding a couple of variables and causal relations, the facilitator summarized by telling the story embedded in the model so far, asking the group to add further causal explanations. After about 90 minutes, the group created the causal structure in Figure 4.

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ASSESSMENT Over the years, the group has experimented with different strategies to elicit model structure from groups. The main limitation of the specific script used in this conference is the risk of having a discussion overguided by the group facilitator, given that client teams may not be used to thinking in loop terms at least at the beginning of the conversation. The main advantage is that it is flexible (used in any situation), and easy to prepare for (the two key stocks were selected during a 15-minute break).

During the beginning of the conversation about structure in this conference, the group showed a tendency to create causal connections from each variable to the rest of the variables in the model. Such a tendency is not rare in client teams. However, the facilitator stressed the importance of a more selective thinking about causality with the purpose of reaching a powerful and parsimonious explanation of the project success.

Initial aggregations such as the aggregation of all project products and activities in a single stock and flow can also create conflict with the client group, who is eager to create a more detailed picture of the problem. Usually, the facilitator or the reflector differentiates between detail complexity (many disaggregated processes), and feedback complexity (a rich feedback story with many loops), explaining that system dynamics modelers have found that it is much easier to increase the detail complexity once an appropriate level of feedback complexity has been reached than to increase feedback complexity when the desired level of detail complexity has been reached.

A very important element in the process is to write down (or erase) all group ideas on the board, even if they cannot be included easily as part of the feedback story. For example, the facilitator in this exercise wrote down inside a hexagon an element of the story important to the client group, but hard to integrate into the story ("Bob used negative experience").

Script 8: reflector feedback

OBJECTIVES Each iteration of structure elicitation is followed by a structured reflection about the group's thinking led by the modeler/reflector. The purpose of the presentation is to summarize dynamic insights and stories told by the group as a recapitulation of the work so far. On some occasions, the activity also serves the purpose of clarifying fuzzy ideas or capturing additional information about model structure needed to formulate the model. In a sense, the exercise is also a translation of the work developed by the group into a more operational diagram that may use pieces of structure generated in previous system dynamics applications. In this translation process, the reflector usually adds value to the conversation by pointing to clearer ways to guide the conversation and model the problem.

PROCESS The reflector's presentation is a story-telling exercise supported by a series of diagrams created by the reflector during the group discussion.

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Diagrams and notes are usually captured in overhead transparencies using markers of different colors. Each diagram presented is accompanied by reflecting the group elements using the words used by the group. Following classic system dynamics practice, a more or less complex structural diagram is presented in different "layers". Each layer is prepared in a different overhead transparency, and transparencies are placed sequentially one over the other in an overhead projector (see Figure 5a–d). The presentation includes comments about how the more operational version of the diagram helps to clarify causal relations and important feedback, and continuous confirmation of the adequacy of the diagram as a representation of the group thinking. Some of the phrases used frequently during the presentation are: "I listen to you talking about . . ."; "the conversation moved then into . . ."; "does it make sense?"; and "does it capture what you were saying?" The presentation took about 15 minutes, and was the last activity of the first modeling day, only followed by a brief conversation of the work to be developed between the two modeling sessions.

The modeler added value to the conversation, showing the process of engagement as a simple diffusion structure or by introducing the idea of "unfeasible prototype components," inspired by the idea of undiscovered rework from other project models in system dynamics.

ASSESSMENT Empirical evidence shows that the reflector summaries of insights are key to a successful exercise of GMB, given that structural insights have a greater impact than detailed causal knowledge on the effectiveness of managing dynamic systems (Maxwell *et al.*, 1994). It helps to capture the main insights from the complex diagrams created during the structure elicitation activities that "overwhelm cognitive capabilities and produce distortions of supposed insights" (Andersen and Richardson, 1997, p. 125). The script constitutes a powerful way to finish a modeling day by helping the group to get a series of structural "chunks" to carry away.

Although the script is designed to be a presentation, listening to the group and using the pen and the eraser continue to be important during the process. During the session described in this paper, the modeler/reflector added variables to the diagram as per request of the group (*perceived validity of the process* and *involvement of the corporate partner*), and added some clarifying ideas to some variable names (comments in parenthesis below *positive prior expectations* and *negative expectations*).

Script 9: transferring group ownership from one image to another

OBJECTIVES After the first GMB session, the facilitation team took notes, diagrams, reference modes and other products from the session to formulate a model based on that set of materials. When they come back to the group, they usually bring a more complex diagram that differs in some extent from the last

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set of diagrams agreed to during the group conversation. This script has two main objectives. The first is to show the group the way in which insights and structures from the first session were incorporated into the simulation model. The second is to "get permission" from the group to continue the modeling work starting with the new structural diagram. The script can also be used to move from a complex diagram created in a structure elicitation activity to a simpler and cleaner version created by the modeler/reflector.

PROCESS The activity starts by projecting on to different walls of the room the different diagrams to be compared. In this particular GMB experience, the second meeting started with a projection of the images in Figures 4–6 in three different walls of the room. Figures 4 and 5 constituted the final "icons" of the group theory from the first modeling session, and Figure 6 was the simulation model formulated between the two sessions. A member of the facilitation team explained to the group how different components of the two diagrams created in the first session were incorporated into the simulation model. The presentation included amplifications of the main sectors of the model to make comparison among the three diagrams easier. The modeling team commented and showed some of the basic assumptions and formulations in the model to the group. At the end of the presentation, the facilitator "asked the group permission" for using the new "icon" as the basis for further theory development. Once the group agreed on the appropriateness of this new "icon", the two images from the first modeling session were taken away, and the conversation focused on the simulation model. The activity extended for about 20 minutes.

ASSESSMENT An important element to consider for an effective result from the script is to maintain visual consistency among the different diagrams. One way to keep visual consistency is to maintain chunks of variables in the same relative position inside the diagram. The rectangles in Figure 6 were not used during the original presentation, but were added here to illustrate that the main "sectors" of the model were kept in the simulation model (the reader can corroborate the existence of these four sectors in Figures 4 and 5). Sector diagrams (Morecroft, 1982) can be used to facilitate the presentation. When further development of some sector of the model is required, the full picture of the model is kept on a wall of the room while the group works on the structure of a particular sector.

Although in many cases model refinement is needed, extensive experimentation with the simulation model precedes any further structure elicitation. In this particular case, the rest of the second GMB session was used to experiment with the model, using different parameter values to get a better understanding of relationships between model behavior and feedback structure. Extensions to model structure are usually guided by group reflections about further steps and the main purpose of the GMB exercise.

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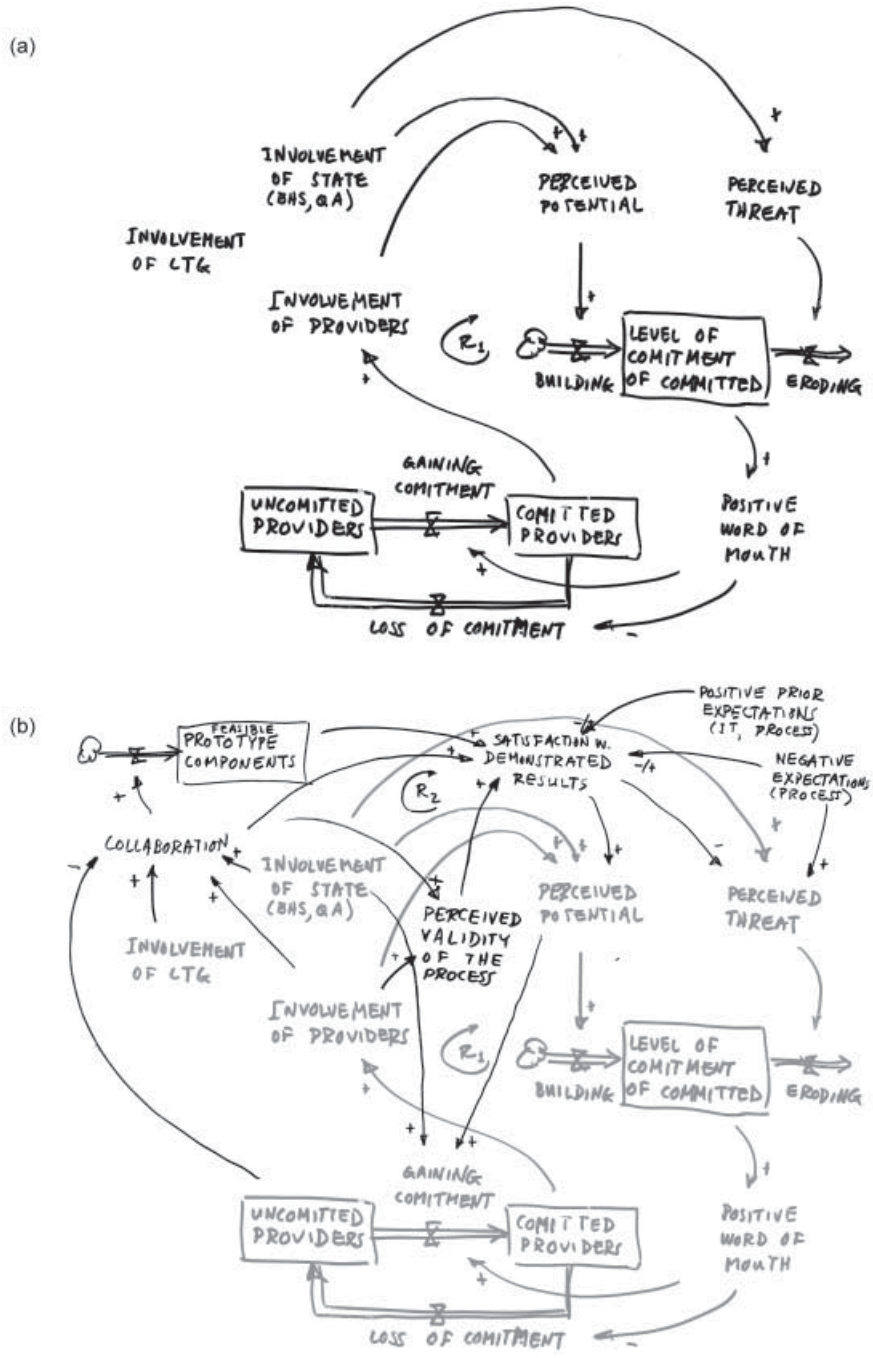

Fig. 5. Layered structure presented during the reflector's feedback (scanned from original overhead transparencies)

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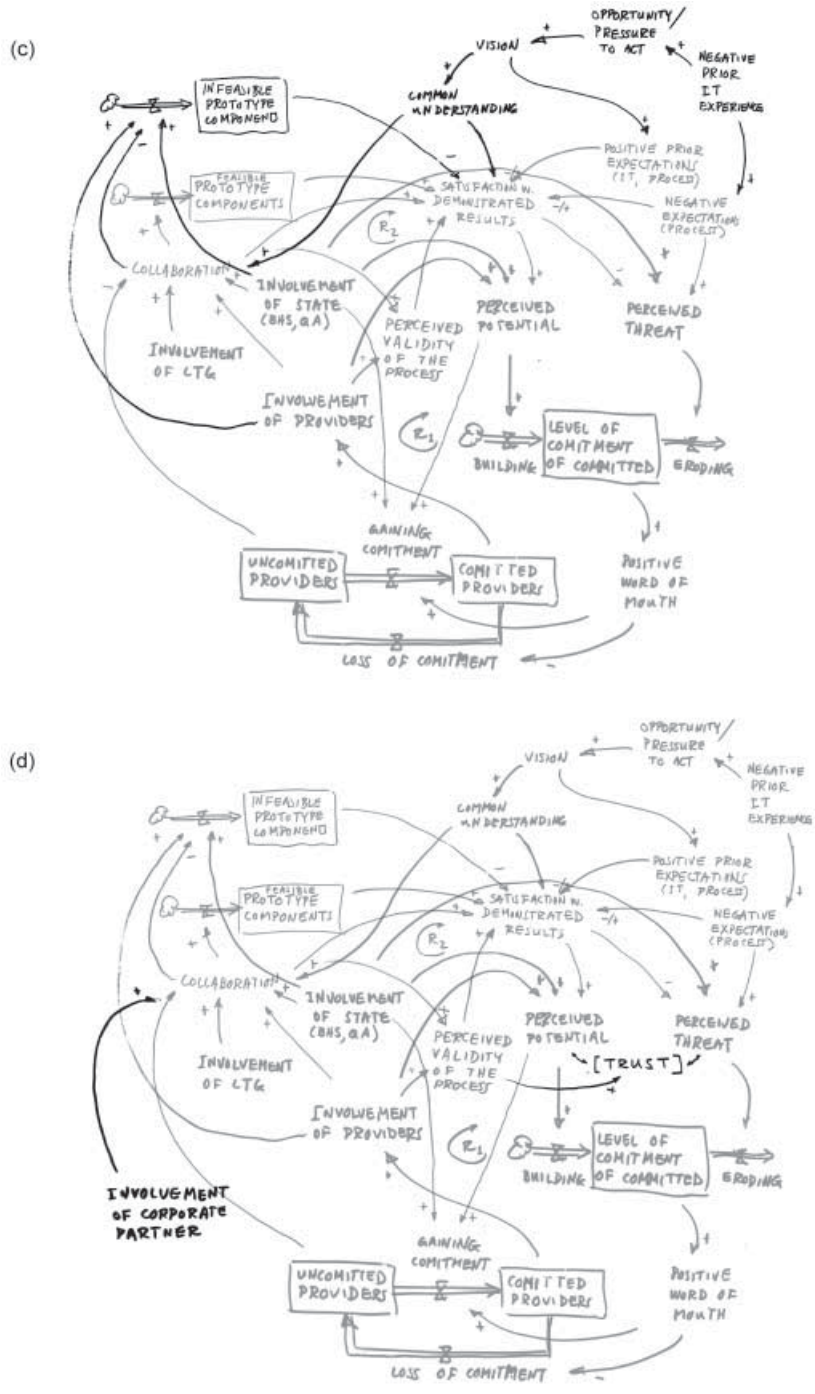
Fig. 5. (*Continued*)



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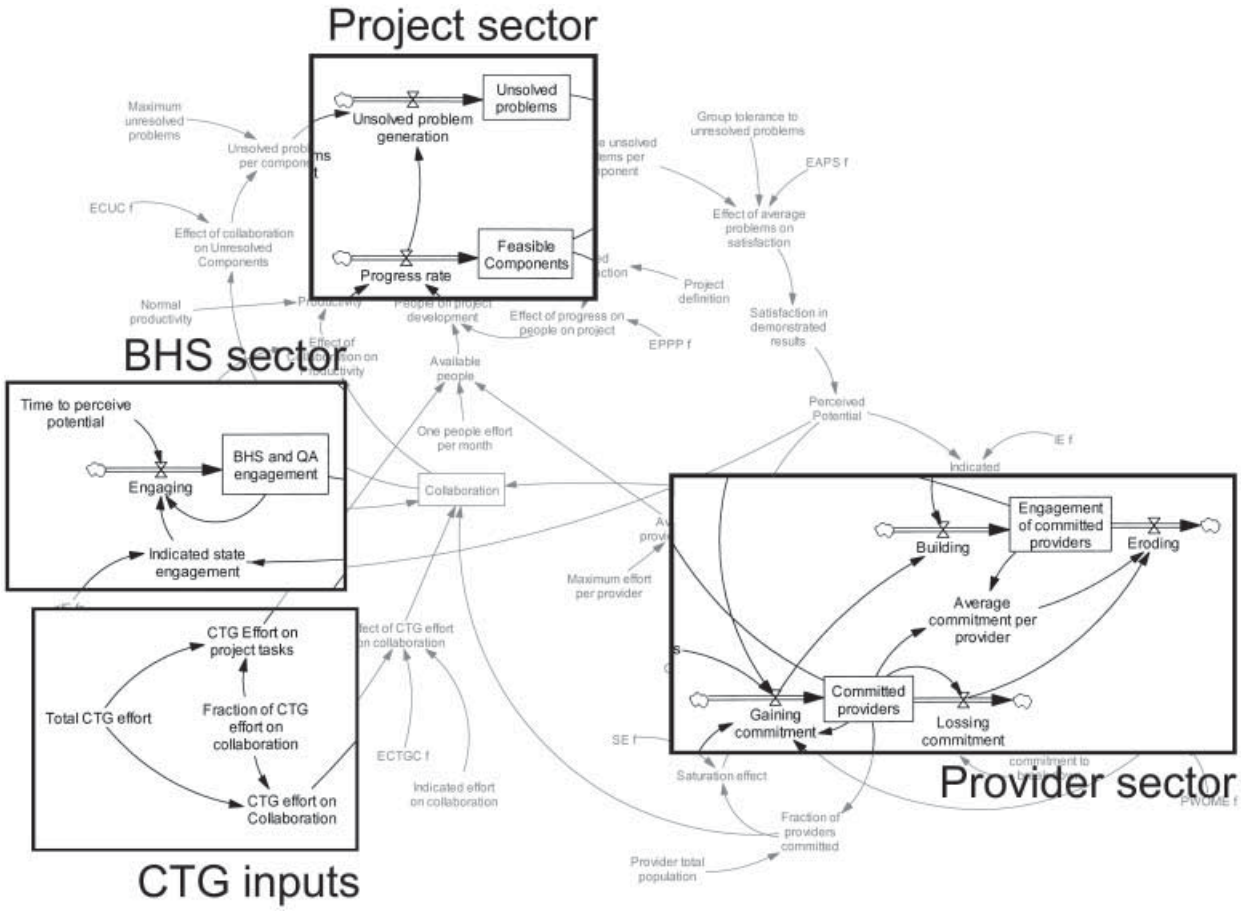

Fig. 6. Main elements in the simulation model presented at the second GMB session

Postscript: project update

General knowledge and understanding from this initial work about trust and collaboration dynamics have fostered a continued effort to clarify specific dynamics found in the HIMS project, and its applicability to other projects at CTG. With the formal incorporation of theory developed by other researchers studying collaboration from a dynamic perspective (L. J. Black, PhD dissertation, 2002), the project has yielded one more presentation at the system dynamics conference (Cresswell *et al.*, 2002), two more papers presented in the HICSS conference in 2003 and 2004 (Black *et al.*, 2003; Luna-Reyes *et al.*, 2004), and a PhD dissertation (L. F. Luna-Reyes, 2004).

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Additionally, the perceived value of system dynamics as a theory-building method by the CTG team triggered the incorporation of a system dynamics component into its longest research project to date, which focuses in the study of interorganizational integration of information.

Summary and conclusion

In this article we have presented detailed documentation of nine different scripts used in a GMB project in 2001. The paper extends the discussion about scripts in GMB (Andersen and Richardson, 1997) by presenting a sequence of scripts that constitute a "soup to nuts" description of the group model building approach at Albany. Along with a detailed description of each script, we presented a series of process-related products in a way researchers and practitioners interested in building models with groups could replicate and use.

This particular intervention demonstrates system dynamics GMB as a powerful tool to build theories on the basis of qualitative case data, and an experienced group of researchers and practitioners involved in the case. The process yielded insights about collaboration that have been reported in the literature, and group commitment to the results promoted continued use of system dynamics to further development of the initial collaboration theory and the formal incorporation of the method in new research projects. However, this new use of GMB opens a series of questions about model validation, and appropriate tests to assess the generalizability, breath, or parsimony of the theory.

Although the number of documented GMB exercises has increased over time, there is a perception of the need for experimental evaluations of the results obtained through these interventions and a framework that facilitates such evaluation (Rouwette *et al.*, 2002). Although calls for empirical evaluation of scripts consider mainly the evaluation of the outcomes of the intervention (Andersen *et al.*, 1997; Rouwette *et al.*, 2002), approaches in decision conferencing argue in favor of process evaluation (McCartt and Rohrbaugh, 1989, 1995).

Issues that may be empirically assessed are common to other GDSS approaches: location of the conference, flexibility of the facilitation, levels of participation in data capture, presentational difficulties, complexity of large volumes of data, control of the team vs. control of the chauffeur/facilitator, group dynamics, conflict, and management of formal and informal languages (Ackermann and Eden, 1994; Kyng, 1995). Some others are particular to the use of system dynamics or particular approaches to GMB: interaction and improvisation among different roles in a conference room or effect of interventions in managers' mental models (Maxwell *et al.*, 1994; Andersen *et al.*, 1997). Documenting and reflecting about different approaches is without a doubt an important step towards the accumulation of replicable knowledge in GMB.

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Notes

1. This paper is based on earlier work contributed by Laura J. Black, Meghan Cook, Donna Canestraro, and Fiona Thompson. Isabel Huerta-Carvajal contributed to this paper in preparing the camera-ready versions of figures and diagrams.
2. For a full documentation of the process-related products, refer to Luna-Reyes *et al.* (2005), presented at the 23rd International Conference of the System Dynamics Society.
3. Decision conferences are "computer-supported meetings in which several decision makers develop an explicit framework or structure for organizing their thinking about an important, non-routine policy or program choice" (Milter and Rohrbaugh, 1985, p. 183). The technique is explicitly designed to combine the strengths of intuition and insight generated by the group with analysis enhanced by the presence of a facilitation team (Schuman and Rohrbaugh, 1991).
4. The processes of group decision making and problem solving have been the subject of considerable attention in the social sciences (Nunamaker, 1989; Ackermann and Eden, 1994; Poole *et al.*, 2004). Actually, as pointed out by Nunamaker (1989), the history of group decision can be traced back to the ancient Greeks and Romans, who used special facilities for work in group decision making and planning. Group decision support systems (GDSS) refer to recent applications of information technologies to support group decision making, ranging from simple applications to brainstorming to systems managing complex participation rules (Quinn *et al.*, 1985; DeSanctis and Gallupe, 1987; Nunamaker, 1989; Nunamaker *et al.*, 1991; Schuman and Rohrbaugh, 1991; Ackermann and Eden, 1994; Zigurs and Buckland, 1998; De Reuck *et al.*, 1999; Barkhi *et al.*, 2002; Quaddus and Tung, 2002; Gottesdiener, 2003). In the particular case of decision conferencing, the group interacts with the information technologies through a facilitation group (Schuman and Rohrbaugh, 1991; Gottesdiener, 2003).
5. The Center for Technology in Government at the University at Albany develops applied research and partnership projects to foster innovative ways to improve government services through the understanding of management, policy, and technology dimensions of information use in the public sector. Additional information about the center can be found in its website at http://www.ctg.albany.edu/.
6. Knowledge Networking in the Public Sector, funded by the National Science Foundation, which the group at CTG refers to as the KDI project.
7. The field research for the HIMS project focused on the development of a prototype of an integrated information system to support evaluation and management of homeless programs and services in New York State. The HIMS prototype integrated data from case management and financial

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systems in several homeless shelter providers. To be successful, the project required participants from the state agency responsible for shelter oversight to work in a highly collaborative way with managers from a wide range of homeless shelters in New York City, Westchester, and Suffolk counties. Because of the diversity among individual shelter practices, shelter managers had the challenge of collaborating among themselves and with the state agency to develop data standards and a common service model.

8. To support our work, we have a written description of room requirements that we can give to a hotel logistics or room manager. In addition, we maintain a fully stocked "meeting box" with colored paper, glue sticks, whiteboard markers, staplers, and all the paraphernalia necessary to run a meeting. These two advance organization items save us immense amounts of time and effort as we move our work off site.
9. For some locations, considerable advance work may be necessary to provide similar meeting arrangements. Many commercial spaces used to support meetings are ill suited to meet these requirements. Working wall space is necessary, but many hotel meeting rooms have textured wallpapers or artwork mounted in ways that prevent posting paper or whiteboard material. Furniture in the form of a fixed long and narrow boardroom table, for example, is poorly suited for a group meeting. Classrooms at a local community college can often be better spaces than hotel spaces. In our group, a story about logistics has achieved legend status. It involves a full professor searching late at night for a grocery store in rural Vermont to purchase cleaning materials, and then spending much of the night cleaning desk surfaces and arranging the furniture in a community college classroom to prepare for a group modeling session the next day.

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